STRUCTURAL PERFORMANCE OF COMPOSITES AT ELEVATED TEMPERATURES DUE TO SHIPBOARD FIRES

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The use of composites inside Naval submarines is now covered by MIL-STD-2031 (SH), Fire and Toxicity Test Methods and Qualification Procedure for Composite Material Systems Used in Hull, Machinery, and Structural Applications [1]. Two guiding criteria [2] were established for the use of composite systems aboard Navy vessels. The composite system will not be the fire source, i.e., it will be sufficiently fire resistant not to be a source of spontaneous combustion. Also secondary ignition of the composite system will be delayed until the crew can respond to the primary fire source, i.e., the composite system will not result in rapid spreading of the fire. The Navy currently has no specific standard for surface ships. The flammability requirements for surface ships are different than submarines. Instead of survivability measured in minutes, as it is in submarine fires, the critical issue in surface ship fires is the residual strength of structures at elevated temperatures for a period of 30-60 minutes.

CDNSWC has initiated a comprehensive effort focused on the issue of residual structural strength of composites during fire. This is intended to result in mathematical models that can be used by naval architects to design full scale fire-tolerant composite structures. This methodology includes determination of basic composite characteristics at elevated temperatures, determination of isothermal material characteristics for use in the computer model, determination of heat transfer characteristics of composite materials exposed to fire, construction of mathematical models using ABAQUS finite element analysis, and experimental validation of these models.

Composites retain most of their load bearing characteristics below a certain "critical" temperature. Above this critical temperature, composites begin to lose their mechanical properties rapidly and, in some cases, catastrophically [3]. To determine the limits of composite structural performance at elevated temperatures, dynamic mechanical thermal analysis (DMTA) was performed on glass reinforced vinyl ester composite panels at various temperatures under isothermal conditions. .

Dynamic mechanical thermal analyzers produce quantitative information on the viscoelastic and rheological properties of a material by measuring the mechanical response of a sample as it is deformed under periodic stress. This method has great sensitivity in detecting changes in internal molecular mobility, determination of the glass transition temperature (Tg), and determination of effects of these changes on load bearing characteristics. The property measured by DMTA that is of interest in determining the load bearing capabilities is the flexural storage modulus, E', which agrees closely with the flexural modulus as measured by ASTM D790 [4]. For dynamic heating scans, E' is a function of temperature. Also important is the ratio of storage modulus to loss modulus, E", as a material passes through the glass transition point. This ratio, Tan δ, indicates the balance between the elastic phase and the viscous phase in a polymer.

P236 PC, a quasi isotropic glass reinforced vinyl ester panel, was exposed to isothermal dynamic

testing at room temperature, 150, 200, 250, 300, 350, 400, 450, 500, 550, and 600^{0}F. All samples were exposed to these different temperatures for a period of 8 hours. In this study, all tests were carried out in a single cantilever bending mode at a constant frequency of 10Hz. Results indicate that the modulus drops at subsequently increasing temperatures. Significant drop takes place between 200 and 250^{0}F. Catastrophic drop takes place between 250 and 300^{0}F.

After the isothermal testing for a period of 8 hours, samples were cooled to room temperature. The samples were retested for dynamic testing to determine the retention of load bearing properties and assess the damage caused to the panels by exposure to the elevated temperatures. If the material retains the viscoelastic behavior, and recovers the load bearing properties, then the damage caused by the thermal exposure is termed as reversible damage. It is important to identify the temperature or thermal aging where the given transition between reversible or irreversible damage occurs. This can be observed in tan δ curves from DMTA scans. Figure 1 shows the results from dynamic testing of glass/vinyl ester panels previously exposed to isothermal conditions at elevated temperatures for 8 hrs. At isothermal aging temperatures up to 450^{0}F, the composite panels exhibit reversible thermal damage. The 500^{0}F DMTA scan shows chemical breakdown of vinyl ester moeity of composite panel and the resin loses characteristic viscoelastic behavior even after the panel has been cooled to room temperature. This resin is no longer capable of transferring the load to the fiber. This is the threshold temperature for irreversible damage.

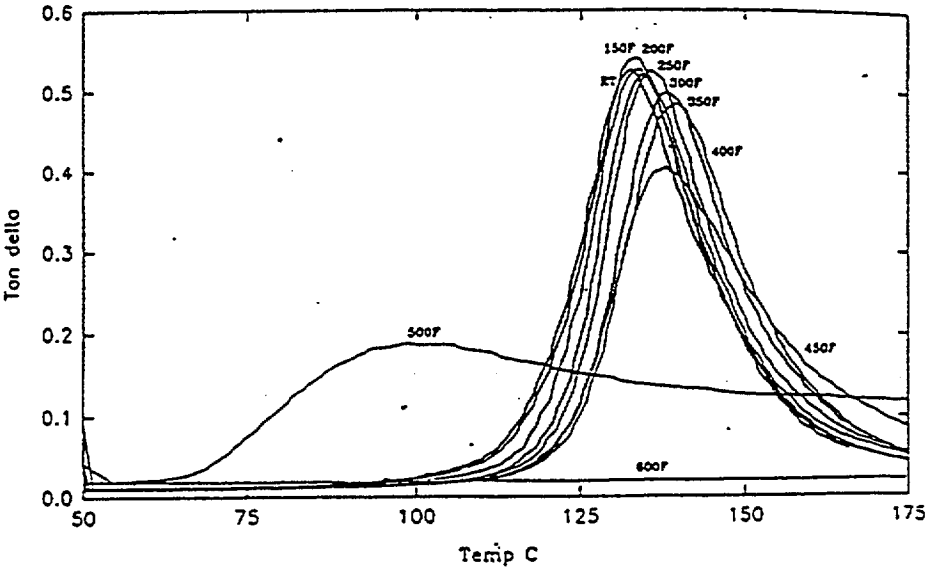

Fig. 1: DMTA scan (Tan δ) for previously isothermally exposed glass/vinyl ester panels.

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